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# Simultaneous desalination and power generation using solar energy

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ABSTRACT

Using solar energy to produce fresh water and electricity simultaneously is a prospective way to solve the problems combining fresh water shortage, energy crisis and farm land degradation in Northern Victoria. This paper records the process of calculating the performance of the nozzle applying homogenous equilibrium model, designing and testing the prototype of such system using three different types of the nozzles in static and rotary systems. The research on the project is divided into two steps: first is about static system in which the spray nozzle is proved to be the best in both production of fresh water and power generation; while on the second stage, the convergent–divergent (C–D) nozzles are the best in rotary system. Some data were analyzed theoretically based on the test and the results found that the percentage of fresh water measured by experiment is consistent with the calculation using homogenous equilibrium expansion model (HEM), however, there is big difference in power generation between theory and experiments. Based on our experimental figures and analysis, the reasons for low power generation are found and a new model is proposed. According to the new model, a different reaction turbine using curve length C–D nozzles is designed to overcome the problems which were encountered in the previous prototype. After analyzing the efficiency of the cycle by *T–s* diagram, the evacuated tube solar collector integrated heat pipe is suggested to be applied on this system.


## 1. Introduction

These days, the limited resources that are usable energy, fresh water and arable land are pestering human being sustainable existences. Firstly, based on the investigation of World Energy Council, although the increase of energy consumption is estimated about 1.7% per year in next 20 years, the situation is still crucial, because the demand of crude oil increases dramatically while the reserves fell by 2.7% [1], especially in China, the demand rate of increase reached 13.21% in 2003 [2]. Secondly, for fresh water, according to the report of UN in 2003, it has been estimated that today more than 2 billion people are affected by water shortages in over 40 countries: 1.1 billion do not have sufficient drinking water and 2.4 billion have no provision for sanitation and the problem is often worst that the population of developing countries living in water poverty at present will increase to 60% by 2020 [3]. At the same time, when humanity has constructed a huge global ecological engineering project to solve the shortage of fresh water and energy crisis, the intervention on ecosystems always results in the negative effects on biodiversity [4], such as the dam of Three Gorges of Yangzi River in China. Lastly, the arable land is decreased due to the saline, deserted and overgrassed. The consultants hired by The Australian Conservation Foundation and the National Farmers Federation predict in a report that Australia is facing the loss of 15.5 million hectares – equivalent to 70% of Victoria – to salinity. The report continues "the estimated total cost of resource degradation is to be more than 2 billion dollars, about half the net annual value of farm production which was 3.9 billion dollars during 1998–1999 – Unless action is taken to address the problems, the annual cost of dry land salinity alone could increase to 670 million dollars in 2020" [5]. For example, in Northern Victoria, the local forests are being killed and grasslands are being degraded due to salting; the deposition of salt was the result of overdrawing underground water for farming and other industrial or household use (Fig. 1). Furthermore, with the development of the industry and the increasing demand, more fresh water and power are needed, while the situation is that the resource is limited. Therefore, finding the sustainable method to satisfy the demand of the fresh water and energy should be one of the most important tasks in the agenda of both the government and researchers alike.

Based on theoretical investigation along with some preliminary experiments it would be possible to simultaneously produce fresh water and power from saline water heated by renewable sources [6]. The project focuses on two aspects: fresh water production and power generation. The principle is that when the hot salt water heated by the solar pond passes through the rotary nozzles driven by the difference of atmospheric pressure and the pressure of the vacuumed chamber, it will vaporize and then condenses into the

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**Nomenclature**

| | |
|---|---|
| $A$ | area ($m^2$) |
| $D$ | diameter of the nozzle |
| $F$ | thrust (N) |
| $R$ | radius (m) |
| $V$ | velocity (m/s) |
| $p$ | pressure (kPa) |
| $x$ | vapour quality in the mixture (%) |
| $C_d$ | drag coefficients |
| $E$ | energy (kJ) |
| $P$ | power (W) |
| $T$ | temperature (°C), torque (N m) |
| $h$ | specific enthalpy (kJ/kg) |
| $s$ | specific entropy (kJ/kg K) |
| $\dot{m}$ | mass flow rate (kg/s) |

*Greek symbols*

| | |
|---|---|
| $\eta$ | efficiency (%) |
| $\nu$ | specific volume ($m^3$/kg) |
| $\rho$ | density (kg/$m^3$) |
| $\omega$ | angular velocity (rad/s) |

*Subscripts*

| | |
|---|---|
| 1, 2, … | arbitrary position |
| c | critical condition |
| g | gaseous phase |
| k | kinetic |
| o | outlet |
| s | system |
| a | absolute |
| d | drag |
| i | inlet |
| l | liquid phase |
| r | relative |
| t | throat |

fresh water, and the mixture exiting the nozzles at high velocity will exert an anti-force on the nozzles, making them rotate which will increase the pressure further, as a result, the velocity of the mixture will increase further and the rotation of nozzles can thus generate more power. Fig. 2 gives the designs of principle system and the actual model is shown in Fig. 3. In the system, the chamber can be vacuumed by an eductor which is connected to cooling water pipe.

This paper mainly contains three types of information. 1. Calculating the performance of the nozzle using homogenous equilibrium model and tests on the static nozzle system engaged to obtain preliminary results for the design and construction of CDP rig. 2. Investigation on the flash flow through the nozzles, conducted by measuring the trust exacted on different shapes and sizes in diameter of throat, and comparing them with the theoretical calculations. Previously many models were set up to solve the safety problems in nuclear power plants [7,8] and to improve the efficiency of two-phase nozzle employed in geothermal turbine [9]; however, as the parameters in our case are different, first-hand research was needed to ascertain the most suitable model to optimize the performance in low temperature and pressure conditions. 3. The test on production of fresh water and electricity generation will be carried out to find out which nozzle is mostly suitable for both stationary and rotary systems. Standards of evaluation will be mainly on power generation and percentage of fresh water production. During the test, results will be compared with experiments and factors affecting the performance will be addressed.

Fig. 1. Trees dying due to the saline coming from the underground water in Pyramid Hill, Victoria.

## 2. Basic calculation and analysis of relative experiments' figures

### 2.1. The experimental instruments

The schematic of the stationary test system is demonstrated in Fig. 4.

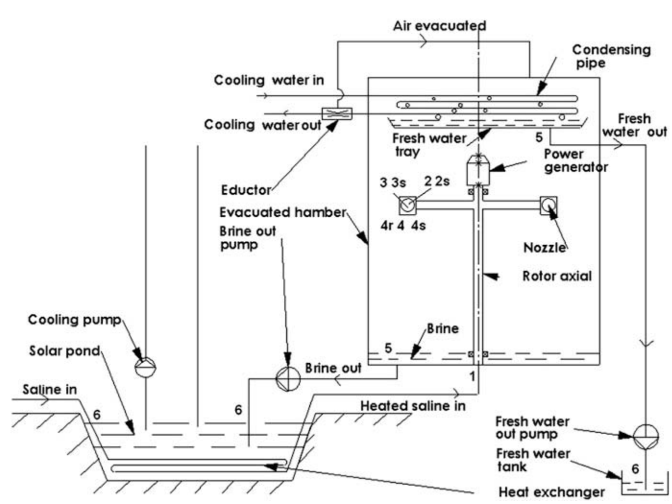


Fig. 2. The principle and the practical system with the fixed nozzles.